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No·till On The Plains

Flourishing without Fallow

by Charles Long

Wallace County, Kansas—on the Colorado border—has the next-to-the-lowest population of any county in Kansas. This is partly due to heavy CRP enrollment 20+ years ago: Every acre of Wallace County qualified for the CRP program, and much of it was signed up. Subsequently, the population dwindled rapidly as the next generation of farmers grew up watching the grass grow on the idled land, rather than raising crops or livestock.

Of that meager population, several operate Homestead Farms. Nathan Pearce—the one available for this interview—provides a rough sketch: "Homestead Farms Partnership is me, my brother, Matt Pearce, and my brother-in-law, Ben Johnson. That's the main farming entity, and we also lease the cattle." Various family members own the 500 cow-calf pairs and lease them to Homestead Farms, which uses them to harvest the 9,000 acres of native grass in the areas too rough and rocky to grain farm.

Of the responsibilities of the partners, Nathan tends to be in charge of crop rotation and selection, fertilizer, and bookkeeping. Matt is in charge of spraying, trucking, and marketing. Ben's a cowboy at heart and is in charge of the cattle operation, in addition to helping out at harvest by running the grain cart and trucks. Nathan says, "My dad is sort of retired, technically not in the operation, but he still helps out—runs a truck when he needs to, or occasionally runs the combine for a day or two." Homestead Farms has three additional full-time employees who are talented enough to be in charge of significant responsibilities on the farm.

Photo by Nathan Pearce.

The Homestead partners love their Shelbournes for preserving stubble.

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Matt and Nathan's dad started no-tilling in 2000/'01, and he was one of two farmers in the county who committed to any continuous no-till since that time. Nathan says, "When we [siblings, spouses] all moved back to the farm in the last 6 or 8 years, we decided to push things a little farther by becoming completely no-till." He continues, "Wheat >>long-fallow is still common and farmers are using full tillage on this. Some will no-till corn into wheat stubble, but then till the ground during the following year [summerfallow] before going back to wheat. . . . We are one of the few in the county who no-till wheat." Nathan says, "We have some fields that have been no-tilled since 2001 or so, and some that we worked [tilled] as late as 2006. We were using excuses like 'too much grass pressure' or 'the ground bakes out during the summer' for working those last fields. Finally we realized that working them only made those problems worse, and crop competition was the only real way to stop the invasive grasses as well as preventing the soil from baking hard. We don't do any tillage at all now."

Converting to no-till: "We were using excuses like 'too much grass pressure,' or, 'the ground bakes out during the summer' for working those last fields. Finally we realized that working them only made those problems worse, and crop competition was the only real way to stop the invasive grasses."

Nathan explains that they've gone a step beyond, by eliminating the problematic long summerfallow itself. After lots of experimentation, their crop of choice for this has become proso millet: "Millet makes the most residue with the least amount of water," thus providing a decent seedbed for wheat in their dry country. Although some will worry about the millet using water as late as August, Nathan says their wheat yields following millet have been very good—nearly as good as chem-fallow wheat. (Their ideal sowing dates for wheat are Sept. 15 to Oct. 15.) However, the proso grain market is a niche, and volatile, but Nathan says that when the price gets too low, they simply spray out the millet just before it sets seed—it instantly becomes a cover crop. Of their 2,900 acres of millet in 2011, they sprayed out 600 acres to determine what effect that might have on wheat yields versus the millet maturing. Their previous experience in 2010 – 2011 was

Photo by Nathan Pearce.

Homestead's corn into wheat stubble, 2010. Long-term corn yields don't need to be particularly high when land rent is $40 – 50/a, as it is where they farm—roughly 25 miles north of Tribune, KS.

Leading Edge

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No-till on the Plains Inc's Mission: To assist agricultural producers in implementing economically, agronomically, and environmentally sound crop production systems.

Objective: To increase the adoption of cropping systems that will enhance economic potential, soil and water quality, and quality of life while reducing crop production risks.

that cover-crop proso appeared to enhance wheat yields over chem-fallow wheat, despite an extraordinarily dry fall and winter. Nathan concludes, “Bare ground from corn or milo harvest until the next year’s wheat drilling is the *worst* thing you can do for establishing wheat in a dry fall.”

Homestead’s 2011 cover-crop proso, sprayed out just before it made seed.

Photos by Nathan Pearce.

Their cover-crop proso makes a great windbreak, even after wheat has been drilled in Sept. 2011. (Yes, it’s been drilled in the photo except for the left 15%.)

Their harvested proso from ’07 (photo: Feb. ’08), also showing the previous corn stalks and wheat stubble. Keeping a thatch over the soil is paramount for the Homestead trio.

Crop Rotation Judo

Nathan thinks of corn as the main crop in their portfolio, with wheat playing a secondary role, and balanced out by “something” else (e.g., millet) that follows their corn and allows good winter wheat establishment afterwards. Nathan says, “We have been doing a lot of corn-on-corn the last several years. Some years it’s not that great, but on some of the better ground and especially the ground with the better no-till history, it is getting more consistent.”

Homestead Farms also grows milo on part of their acres, and where they do plant milo it almost always follows corn. “We haven’t been real happy with milo. I guess we’re high enough elevation and maybe cool enough nights that even in drier years it hasn’t been yielding any different than corn, and corn is worth more and easier to grow for us, easier to harvest, and allows better weed control.” Nathan adds, “Most of our soils are pretty good silt loam, but we have some really high-pH, yellow soils that absolutely won’t grow milo.” However, “Drilled milo in corn stalks will probably stay in our rotation, despite corn being just as profitable over the last few years. Drilled milo adds lots of nice residue and soil structure.”

On chem-fallow: “Bare ground from corn or milo harvest until the next year’s wheat drilling is the *worst* thing you can do for establishing wheat in a dry fall.”

Despite the awkwardness, the partners of Homestead Farms strongly prefer to have “something” else grown between the corn (or milo) and wheat seeding. Nathan says, “We just haven’t had good luck with wheat [directly] into corn [stalks]—like 5 to 10 bu/a.” He continues, “I don’t like [other aspects of] drilling right behind corn either, because sometimes you might get a terrible stand of wheat [despite seeding rates of 120 lbs/a], but even worse you have chopped up all your residue. Then we get those three or four days in a row of 40-mile-per-hour winds out here and your corn residue has all blown into somebody else’s field. We don’t even have choppers on the combines. We just have spreaders. We want those chunks coming out of the combines as big as possible.”

Nathan says that instead of wheat immediately after corn, “I would rather plant some sort of spring crop [to make the transition]. Right now, for us, that’s proso millet.” So, their target rotation on most of their land is wheat >>corn >>corn >>proso (directly to wheat), although, “If we could figure out how to get better milo yields on our high-pH ground, our preferred rotation would be wheat >>corn >>milo >>‘something.' " On those high-pH yellow soils, he's thinking of trying a wheat >>corn >>sunflower >>proso rotation, which has long been a favorite crop sequence of Gary Maskus at Arriba, CO.

For Homestead Farms, not just any crop will suffice for the transition: "*Saf*flower has been tried for a summerfallow replacement. You harvest it in early August. It never yielded very well, though. We were getting about 650 lbs/a, which didn't even meet our expenses." Nathan says the weeds come up very rapidly when the safflower plants stop growing, and it's also messy to harvest with thousands of little oily hairs around the seeds. After two years, his conclusion: "Safflower will *not* work as a summerfallow replacement. It takes too much water [and produces so little residue]. . . . That safflower ground was like drilling into granite." Their wheat stands in the fall of 2010 were an abject failure following safflower.

In 2011, they tried growing field peas for the first time, on a small acreage. With the exceptionally dry fall & winter, the peas didn't have much of a chance. While their area ended up with excellent summer rains, it wasn't soon enough to save the field peas.

Nathan says they'll try field peas again—if they have subsoil moisture—and that they might fill the role, "if we could make enough profit on the peas to offset the lack of residue compared to grass crops like oats or millet." Nathan concludes: "Proso millet has still been our best option for a cash crop during the summerfallow period while giving us a decent seedbed for wheat yet that fall."

"Millet makes the most residue with the least amount of water."

It was dry enough in the fall and winter of 2010/'11 that some of Homestead Farms' wheat didn't make a stand—they sprayed out 50% of it. The decision on what to do with those acres weighed heavily on the Homestead trio, but after extensive analysis of rainfall histories and yield probabilities, they chose to plant corn and milo on all of it. This was partly a result of not having any other palatable options—they didn't want to chem-fallow all summer. And they were able to insure both the milo & corn on the failed wheat, so they weren't entirely rolling the dice on above-average rainfall for the spring and summer. Luckily, they did get sufficient rain to make average to above-average crops on these acres, which also (partly) replenished sorely needed mulch in those fields.

Photos by Nathan Pearce.

Seeding wheat in CRP, Sept. '09. Yep, that's a yucca.

Inset: Seeding wheat in pasture, Sept. 2011 (it's a short-grass prairie).

Wheat's Role

For other rotational permutations, Nathan says, "We haven't had good luck doing more than one year of wheat, possibly because of disease.[1] I don't know if it is the stripper stubble or what. The only time we do two years of wheat is if we have a thin, thirty-bushel wheat crop, or less. Then we do another year. If we have 50-, 60-, or 70-bushel wheat, I don't think we are getting anywhere by putting another year of wheat out there. We would rather go to corn. If we have 50- to 70-bushel wheat stubble, our corn crop planted into that is going to be in really good shape. You have almost complete ground cover."

Homestead Farms seeds their wheat (as well as milo, millet, etc.) with a 42-foot JD 1890 drill on 10-inch spacing, fully loaded with suitcase weights, and a 430-bushel tow-behind cart. The cart was customized so that it's carried on 710 *duals* on the rear. The drill itself is OEM except for Thompson closing wheels—Nathan explains, "The drill does a

[1] No seed treatments were used on wheat previously. Fall 2011 is their first time for insecticide & fungicide on wheat seed.

good job and we aren't terribly unhappy with it, but the [OEM closing] wheels that come with it are about useless."

In the fall of 2009: "We did 1,400 acres of wheat that we no-tilled in CRP ground. We sprayed it starting May 1, sprayed it all summer and no-tilled directly into it with this drill. We are really happy with how the drill went into that ground, and it was even fairly dry at the time. We were getting it 3½ inches into the ground, and the drill did a good job of cutting residue and placing the seed deeply in the CRP mulch. It really turned out to be a good seedbed." Nathan adds, "That wheat did pretty well for us. It turns out that we got such a good stand that we completely eliminated the CRP grasses with just one wheat crop. I actually think wheat into CRP is one of the better ways to bring CRP back into production, at least out here." They did drill the CRP wheat first that fall, at 100 lbs/a of seed (up from their typical 60 – 80 lbs/a) along with 100 lbs/a of Cargill's MESZ compounded fertilizer, and later spread 100 lbs of N as dry urea over the winter. "Both those numbers were based on soil tests on all 1,400 acres, then just averaging [to a uniform rate]. There was so little information and such conflicting information that we felt really confused as to how to fertilize. I guarantee our yields were limited by fertility on this ground."


Photo by Nathan Pearce.

A custom rig spreading feedlot manure for Homestead Farms.

Emphasis on Corn

The farm's 20-year average corn yield is right at 70 bu/a, although with improved farming practices and better hybrids, their average in recent years is more like 80 bu/a. For seed-drop, Nathan says, "It depends on whether it's corn-on-corn, and if it's good soil. It runs from 13,000 to 20,000 in general." Hybrid maturities from 95- to 110-day spread out the pollination timing for managing risk and harvest workload, since about half their total acres are in corn on any given year.

Homestead Farms 'installs' corn with a 24-row CCS Deere planter, equipped with row clutches, Keetons, and Thompson wheels, but *without* row cleaners (nor are there any coulters)—Nathan doesn't think these are necessary. Nor does the planter apply any fertilizers. The planter does have variable-rate planting capability and this is used in some fields. Both the planter and drill share a JD 8360 RT tractor with auto-steer to cover about 13,000 acres of cropland. 2011 was their first year for the tracked tractor, and Nathan suspects they'll eventually end up going back to a 4WD with big radials.

Stalks are never grazed, Nathan explains: "We quit grazing cropland several years ago, because we felt the destruction of the residue was hurting subsequent crops. The traffic from the cattle was breaking residue pieces down to smaller pieces that eventually just blew away—especially wheat stubble. It also caused excessive loss of milo and corn residue." Instead, Nathan says, "On our [native] grass we do rotational grazing, and we raise all-natural beef. We approach cattle the same way we approach farming. We'd like to be as close to the way nature does it as possible. We try to follow the Kit Pharo philosophy of making the cattle feed and raise themselves. We like to put minimal time and money into the cattle. We think of them as combines for the grassy areas—the rocky and canyon-covered ground."

"We quit grazing cropland several years ago. We felt the destruction of the residue was hurting subsequent crops."

All machine harvesting is done by the partnership: Homestead Farms runs two 9770 combines along with two 12-row corn heads, two 30-foot rigid heads (for milo), and two Shelbourne stripper heads for wheat and millet (harvested without desiccation). All the heads have sensors that will allow them to go directly across terraces without slowing down, and both combines have data-recording for yield mapping, as well as auto-steer. Nathan says: "The combines have dual 650s on the front, and we got the biggest single we could get on the back. My dad has always been *very* aware of compaction. . . . I can show you 2010 FSA aerial pictures of some of our fields where you can see exactly where stuff drove in 2009."

Consequently, they actually downsized grain carts, from 1150-bushel to 850s (they run 2 grain carts) carried on 66x43 singles. (*Editors' Note: The diligence in avoiding compaction is highly commendable, especially for 'dry' country. Farmers in wetter climates would do well to take compaction prevention this seriously.*)

Looking Ahead

For N fertilizer, Homestead Farms uses dry urea for all crops, which they apply during the winter with a tractor-drawn New Leader DN 345 spreader. The only other fertilizer used is MESZ, which is applied with their air drill while seeding wheat, millet, and milo; their corn doesn't get P fertilizer. All fertilizers are now VR-applied based on previous crop removal as calculated from yield maps. Homestead Farms has recently added an employee to take charge of their VR and other agronomy work.

In the winter of 2010 – 2011, Homestead spread composted manure on nearly all their acres, which came from a feedlot about 30 miles south of the farm. They applied a set rate of 3 tons/a, which contained a total of about 90 lbs of N and 90 lbs of P_2O_5 which is slowly being released during decomposition. This manure had been properly conditioned to reduce viability of weed seeds, as well as partially decomposing it for faster nutrient release. They plan to re-apply manure after 4 years.

Glyphosate-resistant kochia strikes fear in the hearts of many in western Kansas, but Nathan says they've already adapted to that reality. "Crop competition is the only way to handle kochia—I've never had out-of-control kochia in a crop. But in [chem]fallow, if you let them get started, you'll have them all summer. When they're thick, they get stacked on top of each other, they're stressed, and impossible to kill."

Along with glyphosate + 2,4-D + dicamba burndowns, they usually apply Balance Flexx + atrazine for corn, or else come in post-emerge with Laudis or Status. "For peas and safflower, we've had really good luck with Spartan in early March." Sharpen + MSO has also worked for them on *small* kochia. Plus, there are additional chemistries that they haven't tapped yet.

Some of the worst problems are when someone else lets their kochia get out of control; then the tumbleweeds drift into Homestead Farms' corn pre-harvest, or post-harvest. The outside 12 rows are often unharvestable when this happens.

In the high country of Wallace County, adaptability is crucial. Expect the Homestead Farm siblings and spouses to continue to draw on their inventiveness, critical thinking, and diverse information sources in facing the challenges of the future.

The Biology of Soil Compaction
(Revised & Updated)

by James J. Hoorman, João Carlos de Moraes (Juca) Sá & Randall Reeder

Jim Hoorman is an Ohio State University Extension Educator in cover crops and water quality. Juca Sá is a scientist working on soil organic matter and fertility at Univ. Ponta Grossa, PG, Brazil. Randall Reeder recently retired from Extension Ag Engineering, Ohio State Univ., specializing in soil compaction.

Editors' Note: Modified extensively from an Ohio State Extension Fact Sheet, 2009, in collaboration with Hoorman & Sá, along with the generous assistance of John Grove (soil scientist, U.Ky.), Tom Schumacher (soil scientist, SDSU), and Kris Nichols (mycorrhizae scientist, USDA-ARS).

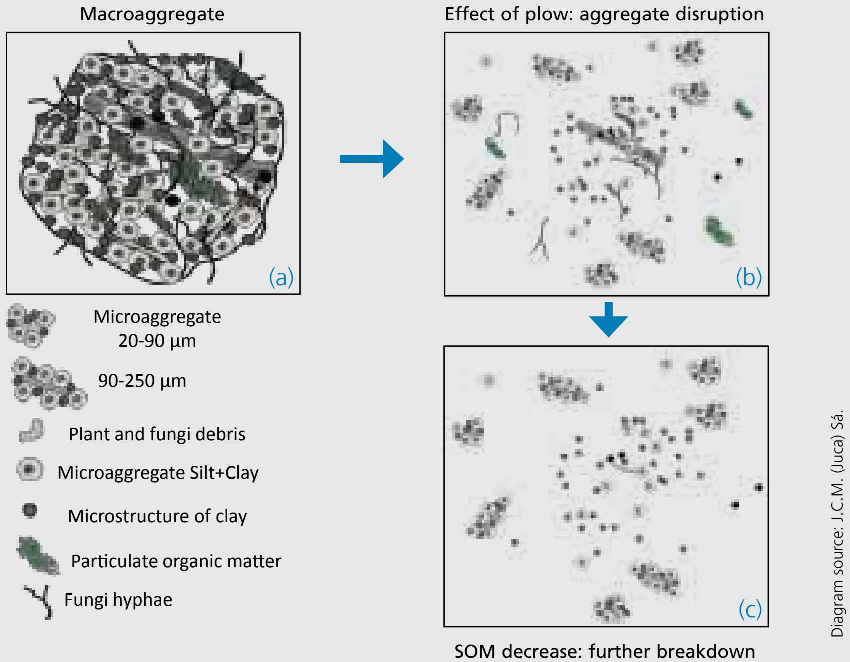

Figure 1: (a) Macro-aggregate components—schematic illustration; (b) Mechanical disturbance by tillage disrupts macro-aggregates, and exposes soil organic matter (SOM) protected within the aggregate to microbial attack; (c) loss of SOM within the aggregates (due to microbial digestion) causes destabilization of linkages in the macro-aggregate, making them vulnerable to collapse from external forces. *Macro*-aggregation gives soil most of its structure, porosity, aeration, and the ability to resist compacting forces. The smallest macro-aggregates are the size of the period at the end of this sentence, and range up to about the size of this letter 'O.' *Micro*-aggregates are smaller than the period, and some are microscopic.

Soil Compaction

Soil compaction is a common and constant problem on most farms that till the soil. Heavy farm machinery can create persistent subsoil compaction, even when under no-tillage management.[1] Scientists have found that compacted soils resulted in: (a) physically restricted root growth; (b) poor root-zone aeration (inadequate oxygen flow to roots); and (c) poor drainage that contributes further to poor soil aeration and to more losses of nitrogen from denitrification.[2]

Subsoil tillage has been used to alleviate compaction problems. Subsoilers (deep-rippers) are typically operated at depths of 12 to 18 inches to loosen the soil, break compaction, and increase water infiltration and aeration. Subsoiling sometimes increases crop yields but the effects may only be temporary because the soil re-compacts from rainfall as well as continued equipment traffic over wet soil. Some no-till fields never need to be subsoiled, but in other no-till fields deep tillage has increased yields, especially if equipment traffic has occurred over a large portion of the field while soils were wet. When subsoiling removes a hard pan, traffic must be controlled or compaction will re-occur. If a hard pan does not exist, equipment traffic on damp soils can create one.[3] (*Editors: Research and farmer experience across much of the USA indicate that yield increases from deep tillage are rare, and short-lived. Hard pans are primarily the result of tillage implements, and not so much from wheel traffic. And, in continuous no-till, controlled traffic [permanent tramlines] on terrain with any significant slope creates major problems, due to runoff carving rills and gullies in the permanent traffic lanes.*)[4]

The required fuel, labor, equipment, and time make subsoiling an expensive operation. If the field is sub-

1 I. Hakansson, & R.C. Reeder, 1994, Subsoil compaction by vehicles with high axle load—extent, persistence and crop response, *Soil Tillage Res.* 29: 277–304.
2 B.S. Johnson, A.E. Erickson & A.J.M. Smucker, 1986, Alleviation of compaction on a fine textured soil, ASAE Paper No. 86-1517, ASAE (St. Joseph, MI).
3 R. Reeder & D. Westermann, 2006, Soil Management Practices, in: *Environmental Benefits of Conservation on Cropland*, ed. M. Schnepf & C. Cox, Soil & Water Conserv. Soc. (Ankeny, Iowa) (pp 26–28).
4 *Tom Schumacher agrees fully with the Editors' comments and summary of the science, noting that favorable outcomes from subsoiling are usually confined to breakage of geologic or chemical hardpans (fragipans), and not those created by tillage or wheel traffic.*

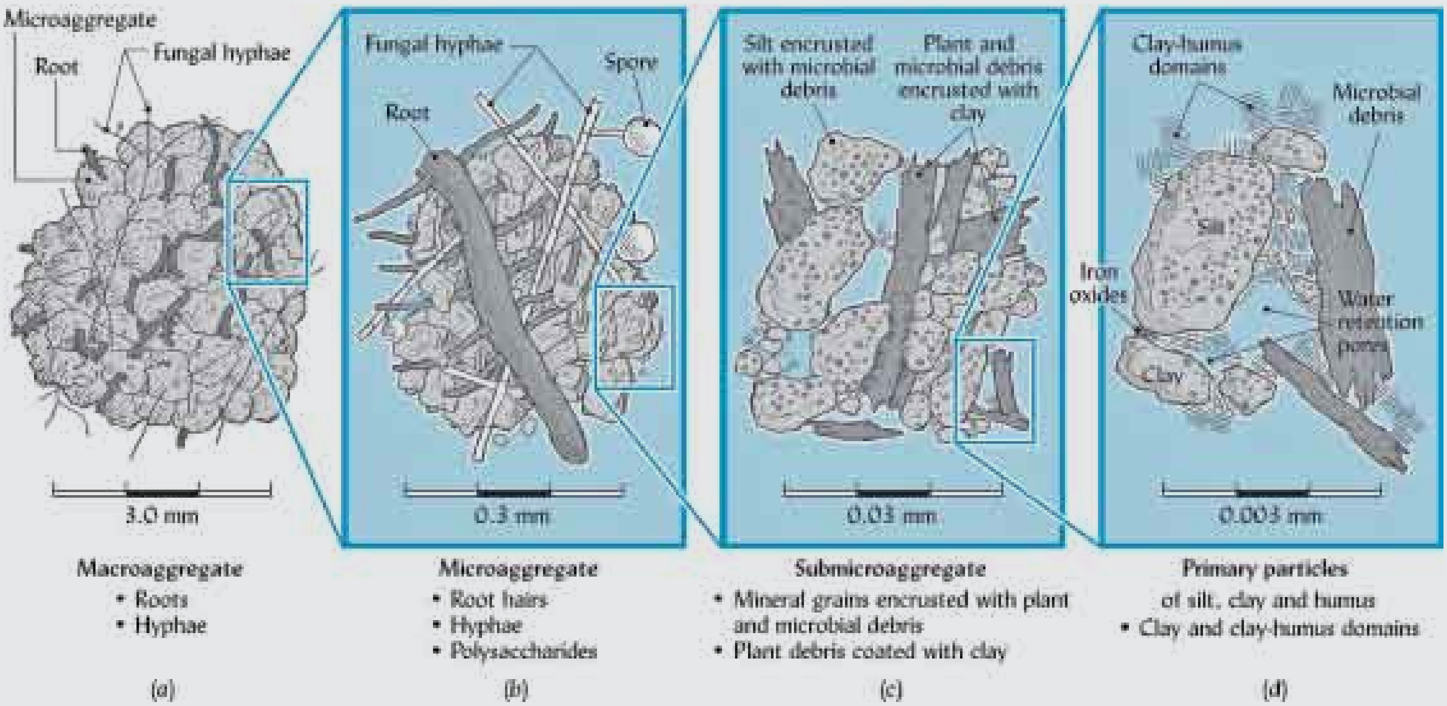

Figure 2: Peering deeper into the structure of soil aggregates. Units of measure **μ** = micrometer (millionth of a meter). Reprinted with permission from N.C. Brady & R.R. Weil, 2008, *The Nature and Properties of Soils,* 14th ed. (p 137, fig. 4.15).

soiled when it's wet, additional compaction will occur. Subsoiling dry soil (although more effective) requires even more fuel.[5] Soil texture and structure play a role in compaction. In a loamy sand with little soil structure, researchers found that soil compaction increased with time, and that cumulative rainfall accounted for 70 to 90% of surface and subsurface re-compaction, due to water movement through the soil and the force of gravity.[6] Such phenomena are less important on *well-structured* loamy and clayey soils. However, in tilled soils, compaction readily increases from the force of rain-drop impact on bare soil as well as water percolation through unstable pores and voids.

The 'root-hyphae net' holds the aggregates intact.

Crop residues (mulch) on the surface have been shown to cushion the effects of soil-compacting forces. These crop residues can be compressed, but also retain their shape once the traffic has passed. Like a sponge, the organic material then springs back to its normal shape. However, excessive traffic breaks up crop residues, and tillage accelerates decomposition of soil organic matter ('SOM': basically anything in the soil that lives or once lived, including remnants of plants, microbes, and their secretions). Low SOM levels make the soil more susceptible to compaction.[7] Crop residues *within* the soil (roots and root exudates) may be even more important than surface residues for preventing compaction.

In the last hundred years, tillage has decreased SOM levels by 60%, which means that approximately 40% of the soil organic carbon stock remains.[8] Carbon compounds provide energy for soil microbes, are a storehouse for nutrients, and help maintain nutrient cycling between plants and soil. Humus is the highly decomposed and most stable carbon type that binds individual soil particles (microscopic clays) together to form micro-aggregates. As compared to younger 'active' carbon, humus is less water soluble and isn't readily consumed by microorganisms, thus stabilizing the micro-aggregates (see Fig. 2). Humus is more resistant to tillage and microbial degradation than active carbon. Some of the more durable SOM components are centuries old.

Active carbon (plant sugars or polysaccharides; glomalin; proteins) is consumed by microbes for energy. Active carbon is reduced with tillage but is stabilized under natural vegetation and no-till systems using a continuous living cover. Active carbon is part of the 'glue' that binds smaller aggregates into larger aggregates and stabilizes the arrangement. This is how soil porosity, water infiltra-

5 Reeder & Westermann, 2006.
6 W.J. Busscher, P.J. Bauer & J.R. Frederick, 2002, Recompaction of a coastal loamy sand after deep tillage as a function of subsequent cumulative rainfall, *Soil Tillage Res.* 68: 49–57.
7 C.S. Wortmann & P.J. Jasa, 2003, Management to Minimize and Reduce Soil Compaction, *NebGuide G896*, U. Neb.–Lincoln Extension.
8 R. Lal, 2004, Soil Carbon Sequestration Impacts on Global Climate Change and Food Security, *Science* 304: 1623–1627.

tion, aeration, and structure increase under natural vegetation and no-till systems with continuous living cover.

Aggregate Formation

Micro-aggregates are silt-sized (20 – 250 µm, or less than 0.01 inch), relatively stable, and composed of clay microstructures and microscopic bits of organic matter. *Macro*-aggregates, greater than 250 µm in size, are linked mainly by fungal hyphae, root fibers, and their glue-like secretions. These larger aggregates are less stable than micro-aggregates, but it is the macro-aggregates that give the soil structure and allow greater air flow and water infiltration. The macro-aggregation lowers bulk density (increases stable pore space) and provides most of the resistance to compacting forces. Compacted soils tend to have more micro-aggregates than macro-aggregates. (Fig. 1 & 2)

Fungi live longer than bacteria and need more stable conditions. Since fungi don't grow as well in tilled soils, fewer hyphae are produced and fewer macro-aggregates are formed.

'Glomalin' is one of the organic glues that holds aggregates together. In order for glomalin to be produced, plants and mycorrhizal fungi must coexist: The mycorrhizal hyphae threads are allowed to enter the root, where the plant 'trades' sugars for nutrients and water from the fungus. Glomalin is an 'amino polysaccharide' or 'glycoprotein' created by combining a protein from the mycorrhizal fungus with a complex sugar (polysaccharide) from plant roots.[9] Roots exude (secrete) other organic compounds that coat soil particles. (Fig. 2 – 4)

The 'root-hyphae net' holds the aggregates intact, and clay particles partially protect the roots and hyphae from attack by microorganisms. The contribution of mycorrhizal fungi to aggregation is a process involving three simultaneous actions. First, the fungal hyphae physically entangle soil particles, meshing them together. Second, fungi physically protect the clay particles and organic debris that form micro-aggregates. Third, the plant root and fungal hyphae form glomalin that glues micro-aggregates and smaller macro-aggregates together to form larger macro-aggregates. (Fig. 4)

Photo by J.C.M. (Juca) Sá.

Figure 3: Roots, fungal hyphae, and their secretions stabilize soil aggregates and promote good soil structure, thus preventing compaction.

Glomalin needs to be continually produced because it is readily consumed by bacteria and other microorganisms in the soil. Bacteria thrive in tilled soils because they are more hardy and smaller than fungi, so bacteria numbers can increase rapidly in tilled soils when conditions are favorable. Fungi live longer and need more stable conditions to survive. Fungi grow better under no-till soil conditions with a continuous living cover and a constant supply of carbon food source. Since fungi do not grow as well in tilled soils, less glomalin and fewer hyphae are produced and fewer macro-aggregates are formed. **Thus, susceptibility of soils to compaction is a direct result of a biological problem: Decreased amounts of roots, hyphae, and their secretions in the soil.**

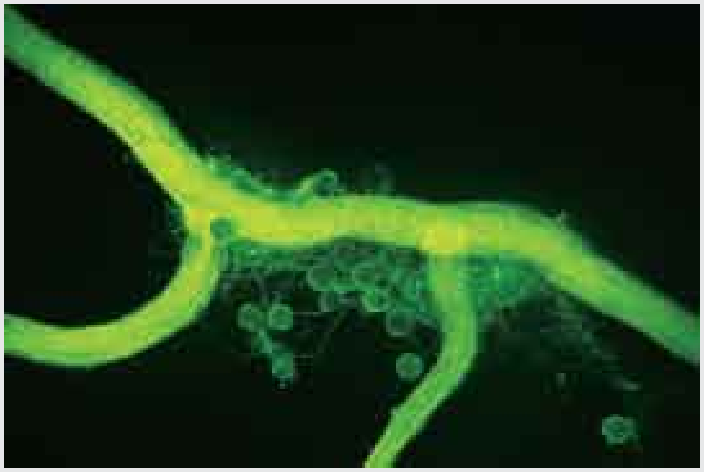

Photo by Sara Wright & Kris Nichols, USDA-ARS.

Figure 4: A microscopic view of an arbuscular mycorrhizal fungus growing on a corn root (the most prominent item in the photo). The round bodies are spores, and the threadlike filaments are hyphae of the fungus. The substance coating them is glomalin, revealed by a green dye tagged to an antibody against glomalin.

[9] S.F. Wright & A. Upadhyaya, 1996, Extraction of an abundant and unusual protein from soil and comparison with hyphal protein of arbuscular fungi, *Soil Sci*. 161: 575–586; S.F. Wright, M. Franke-Snyder, J.B. Morton & A. Upadhyaya, 1996, Time-course study and partial characterization of a protein on hyphae of arbuscular mycorrhizal fungi during active colonization of roots, *Plant & Soil* 181: 193-203; F.E. Allison, 1968, Soil aggregates—some facts and fallacies as seen by a microbiologist, *Soil Sci.* 106: 136–143.

In a typical two-year corn-soybean rotation, a significant quantity of active roots is present only a third of the time.[10] Adding cover crops after both the corn and soybeans increases the time that roots are actively growing by several months. Active roots produce more polysaccharides, which permits more hyphae and glomalin production because mycorrhizal fungus populations increase with the stable food supply.

In a corn-soybean rotation, active roots are present only 1/3 of the year. Cover crops increase the time roots are actively growing by several months.

Aggregate Loss

Surface and subsoil tillage may physically break up hard pans and soil compaction temporarily but they are not a permanent fix. First, tillage decreases mycorrhizal fungus populations. In a typical undisturbed soil, mycorrhizal hyphae are turned over (grow, age, die) every 5 to 7 days (the fungus organism may live far longer, but its finely branched absorptive hyphae must continually regrow), which provides a continuous supply of glomalin as well as more hyphae.[11] Second, tillage sharply increases oxygen flow to soil microsites,[12] thus speeding microbial decomposition of glomalin, hyphae, fine roots, and the other organic materials that create the structure needed to resist compaction. Disturbed soils have fewer fungi, more bacteria, and more micro-aggregates than macro-aggregates. Heavy equipment loads and rainfall can then push the micro-aggregates into tighter arrangements, thus decreasing the pore spaces. In other words, compacting the soil. (Fig. 5) However, macro-aggregate formation improves soil structure and its ability to resist compaction.

Cultivation of soils causes the breakdown of macro-aggregates, which are a large component of soil structure ('tilth'). Farmers who excessively till their soils[13] (e.g., repeated use of the plow, disk, sweeps) break down macro-aggregates by mechanical shattering and by allowing extra oxygen to get to the soil's microbial decomposers, thus depleting the soil of glomalin, polysaccharides, and other carbon. Greater than 90% of soil organic carbon exists as a coating on the mineral surfaces of clay, silt, and sand particles.[14] These stabilizing carbon compounds are consumed by aerobic bacteria that flourish at higher soil oxygen levels[15] (there are other bacteria that thrive when soil oxygen is extremely low). The end result is a soil composed mainly of micro-aggregates and much more prone to

Macropores act like pipes to control the rate at which oxygen reaches roots and soil microbes. Roots need oxygen. However, big influxes of oxygen result in rapid soil carbon loss because the aerobic microbes can then consume organic compounds faster.

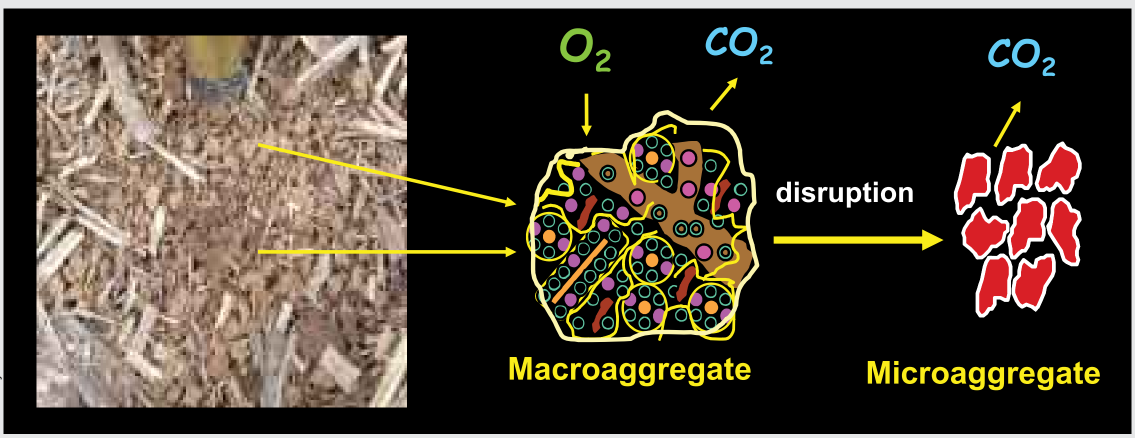

Photo by Juca Sá.

Figure 5: Tillage disrupts the macro-aggregates by physically breaking them into micro-aggregates and by exposing the organic 'glue' to bacterial digestion. Source: Juca Sá.

10 *Editors: Unless the field has a lot of winter annual weeds.*

11 C. Hamel & C. Plenchette, 2007, Extraradicle Arbuscular Mycorrhizal Mycelia: Shadowy Figures in the Soil, in *Mycorrhizae in Crop Production*, ed. C. Hamel & C. Plenchette, Haworth Press (hyphae die after a few days but resist decomposition and still function as a conduit in the hyphal network).

12 *Editors: This is partly due to drying as a result of tillage—every soil aggregate has a water film surrounding it, even in the driest of field conditions. As the water films get very thin (e.g., drying by tillage), oxygen need not diffuse very far through water to reach the microbes and SOM. Oxygen diffuses 10,000 times more slowly through water than through air, so the thickness of these water films is major factor in the rate of decomposition and loss of SOM.*

13 *Editors: In our view, virtually all tillage is 'excessive.' Unless you're installing a highway.*

14 J.D. Jastrow & R.M. Miller, 1998, Soil aggregate stabilization and carbon sequestration: Feedbacks through organomineral associations, in: *Soil Processes and the Carbon Cycle*, ed. R. Lal et al., CRC Press (Boca Raton, FL) (pp 207–223).

15 Tillage causes this 'mineralization' which is the release of mineral nutrients (N, P, S, etc.) and carbon from organic matter (decomposition exceeds the rate of sequestering / immobilization, a.k.a. 'tie-up').

compaction. Soils composed mainly of micro-aggregates have slower water infiltration due to a lack of stable macropores, so water tends to pond at the surface. Fields that have been excessively tilled tend to crust, seal, and compact more than no-till fields with plentiful crop residues and a living plant cover with active roots and fungi.

Agriculture that combines **a continuous living cover with continuous long-term no-till** is a system that closely mimics a natural ecosystem and **will improve soil structure and soil productivity.** A continuous or nearly continuous living cover plus continuous long-term no-till protects the soil from compaction in four major ways. *First*, the organic material on the soil surface acts like a cushion, helping to absorb the weight of heavy equipment traffic (as well as the force of planter or fertilizer openers). *Second*, plant roots create and enlarge voids and macropores in the soil so that air and water can move through the soil. These macropores act like pipes to control the rate at which oxygen reaches roots and soil microbes. The soil needs oxygen for root respiration and to support aerobic microbes in the soil (the same way we metabolize food, with carbon dioxide as by-product). However, big influxes of oxygen result in rapid soil carbon loss because the aerobic microbes can then consume organic compounds faster. *Third*, plant roots supply food for microorganisms (especially fungi) and burrowing soil fauna (e.g., earthworms) that create and maintain soil porosity by their activities. *Fourth*, roots help stabilize soil aggregates. The most stable, durable combination is where aggregates are held together by humus or old organic matter that resists decomposition. A more temporary combination is the linkage by newer plant polysaccharides and fungal glomalin, but these are more easily digested by bacteria so they need to be continually replenished to maintain or improve soil structure. This process is broken when the soil is disturbed or tilled, or lacks vegetation.[16]

Compaction is a result of macro-aggregate depletion by tillage.

Summary

Soil compaction reduces crop yields and farm profits. For years, farmers have been physically tilling and subsoiling to alleviate soil compaction. At best, tillage may temporarily reduce soil compaction but rain, gravity, and equipment traffic will re-compact it. A soil's vulnerability to compaction is largely a result of biological aspects: Living plants with active root systems, along with mycorrhizal hyphae, and the glue-like secretions of each, will significantly reduce compaction susceptibility. Year after year, this process can improve soil structure considerably and provide resistance to compacting forces. Thus, a continuous living cover and long-term no-tillage management act together to reduce soil compaction occurrence.

Tillage increases the rate at which oxygen is supplied to microsites in the soil, thus increasing aerobic bacterial populations which consume the carbon compounds that stabilize macro-aggregates. This leads to loss of soil structure. Soil compaction is the result of traffic (or the compressing forces of tillage itself) on moist soils where tillage has previously destroyed macro-aggregates. Rainfall also causes compaction where macro-aggregation has been depleted by tillage, due to flow of infiltrated water through the destabilized pores and voids, and also from raindrop impact onto barren, exposed soil.

Further reading: Tom Schumacher & Walt Riedell, 'Soil Structure Examined,' Leading Edge, *Jan. '08, pp 398-406.*

What is a clod?

Many farmers complain that their soil is cloddy and hard to work. Clods are man-made and do not usually exist in the natural world. Bricks and clay tile are made by taking wet clay from the soil, forming it, and then heating (firing) and drying the clay. When farmers do tillage, they perform the same process by exposing the 'formed' clay to sunlight, which heats and dries the soil shards until they are hard clods. Tillage also causes greater microbial decomposition of plant residues and soil organic matter which would normally keep silt and clay particles from hardening with drying. Crop residues act like sponges, absorbing water and cushioning against the force of surface traffic and raindrop impact.

Photo by Jim Hoorman.

[16] A fifth mechanism exists: On a dry-weight basis, SOM is lighter and less dense than clay and sand particles: The average bulk density of SOM is 0.3 to 0.6 g/cm^3 compared to bulk soil density of 1.4 to 1.6 g/cm^3. So gaining SOM will decrease the average soil density directly, albeit ever so slightly—since SOM is so slow to be regenerated, and most mineral soils contain only a couple percent SOM.

Long Odds Yet

by Matt Hagny

Mindemann was the cover story of the March '05 issue.

For Alan Mindemann, a true pioneer of no-till cropping in southwest Oklahoma, 2011 has been harsh. Not just the worst drought on record—he also is losing a fair chunk of his rented cropland (due to circumstances, not his farming methods). Yet, he sees opportunity. A mirage, you ask?

"Looking back at my farming history, some of the highest returns I've ever had were in drought years. We always caught the one rain [to make a crop]," says Alan. That didn't happen in 2011, although he thinks he has some cotton to harvest where he caught an inch (total) of rain since planting (starting with a full profile of moisture, in wheat/dc milo stubble). Alan's corn & milo failed, but he had perfect stands—while most in the neighborhood didn't get a stand on any summer crops. As for his usual sesame acres, "I never had a chance to plant it. I would've had to plant 2 inches deep to get to moisture, and sesame won't come from that depth." He did eek out about 1/3 of a wheat crop.

In Sept., Alan's big concern was lack of moisture to establish a cover crop: "I'm going backwards on residue." In general, he plans for more seed-wheat acres for 2012. For production, "Wheat's the surest bet"—although he questions the validity of his statement, noting very poor wheat crops in '06 (drought), '07 (flood), '09 (late freeze), and drought again in 2011. "My summer crops and double-crops saved my butt in those years, but not this year."

Several things Alan won't compromise on, regardless of weather and other duress: "I won't pasture wheat. Let's put it this way: I won't plant wheat early enough to pasture. It's just asking for trouble with Hessian fly." Nor on crop nutrition: "Shorting your fertility program is a dead-end road."

Alan now has on-farm storage for liquid N, which lets him buy ahead. This, his only N source, is stream-applied with his Apache sprayer. P fertilizer goes on as 18-46-0, either with his 30-ft JD 1890 as pop-up, or surface broadcast. Some crops put in with his 16-row planter get 10-34-0 via Keetons.

"Gypsum is a cheap source of sulfur, and improves soil structure."

Alan applies zinc sulfate aggressively—usually with his wheat pop-up—and b'casts potassium chloride (0-0-60) on sandy soils. In targeting soil pH of 5.5 – 6.0, he assiduously applies lime (calcitic), although only 1 – 2 tons/a/yr, regardless of the lab's recommendation—he's had trouble with larger amounts reducing yields (inducing micronutrient deficiencies, etc.).

Alan routinely uses gypsum (calcium sulfate) for sulfur, noting that his soil tests show sulfate-S of 40 – 50 ppm for many years after the application, versus ~ 10 – 20 ppm otherwise. "Grandpa always talked about everyone using gypsum on the 'red land' to make tillage easier. They applied it every few years." Yet Alan has no target level for calcium in his soil; he simply applies 1 t/a of gypsum when he needs sulfur—about every 8 – 10 yrs. "It's a cheap source of sulfur, and it does improve soil structure." He adds, "Our gypsum source [quarried] has a lot of copper and other micros in it."

In the past 7 years, "Double-cropping replaced almost all my cover-cropping." Alan typically grows milo after wheat or canola harvest, although he's also done dc corn, soybeans, sunflowers, and sesame. Alan was an avid corn grower in '03 – 2010, due to the $0.80 – 1.00 premium over milo, but now that they're on par, he opts mostly for milo: "Similar yields, but milo is cheaper to put in."

Alan was 'gonzo' on winter canola for a few years, to the tune of 800 a/yr, plus buying a pusher to artificially lodge the crop just prior to maturity, as an alternative to swathing. But his crop often wasn't thick enough to make the plants interlock with the pusher (some areas of fields wouldn't grow out normally in the spring, and he hasn't figured out why). So, in '09 & 2010, he simply returned to sesame (grain) as more lucrative and user-friendly than canola.

During the worst drought on record, with no end in sight (as of Sept. 2011), Alan's still eager to regain his acre base for 2012. (Risk-averse, he isn't.) On whatever new land Alan acquires, he's no longer interested in deep-ripping: "It causes more problems than it helps. Ripping causes rutting, and then you gotta till the ruts. *Tillage begets tillage*. Now, I try to let the soil heal itself—and I can help that along with cover crops."

Smooth Operator

by Roger Long

Anyone who talks farming in-depth with Tom Pauly, Conway Springs, KS, realizes that it's economics that steers his boat, that more bushels produced at lower costs is what makes the best business sense, and no-till is the means to the end. Thirty miles southwest of Wichita, he's a resident of the juggernaut of wheat production, Sumner County—which, in acres, eclipsed the next largest county in the "wheat basket" state by 50% in '09, and is more often than not the top county in KS in bushels produced.

But with 30-year-average precipitation of over 32 inches, Tom knows there's great potential for more than just wheat: "I don't like to see water run off the farm. I want to capture every bit that falls. On average, we get plenty of rain through the year but it generally doesn't come very timely." Tom also knows that along with improved rain capture in his fields, he both could and should pull more water from the soil with grain crops—and, lately, with cover crops too. Wise observations from a seasoned no-tiller, but he wasn't always an avid proponent of low soil disturbance.

Nudged into no-tilling in '99, Tom was feeling the labor crunch of needing to get fields planted, but not having his sons around any longer to work the ground. He started no-tilling one field out of necessity, and over a six-year period, eventually converted to 100% no-till. In drier regions, growers switch to no-till to conserve moisture, but the catalyst that took this no-tiller from dipping his toes into the water to full immersion was the rainfall before and during planting season: "Too many times, in between finishing a field with a field cultivator and planting, rains would come and the field would need to be re-worked." Already short on manpower, the immediate need for labor-saving techniques was looming. Pauly was slowly converting to no-till, still doing some tillage where time allowed, when a real "toad strangler" rain came in the fall. By this time, he had direct comparisons in his own fields to study and it soon became quite obvious that no-till wasn't just a labor-saver, but a soil-, nutrient-, and moisture-saver as well.

If those humbling experiences weren't enough, Tom embarked on the No-till on the Plains' Points North Tour about then, which peeled back more layers of the proverbial onion. "I went because I wanted to learn how to grow no-till continuous wheat." The Tour gives growers a multi-day portal into no-till agriculture, visiting the farms of experienced no-tillers who have succeeded through their own innovation, and to a great extent being a disciple of Dwayne Beck. But Tom *didn't* learn how to grow continuous wheat. What he did learn—surprise—"You don't *have* to grow that much wheat." Tom now concedes, "I've made more money off of soybeans than anything else the last several years."

Still No Panacea

While proud of his progress, Pauly has no illusions of an 'arrival' or that all problems have been solved. Instead, all his faculties are focused on sound agronomic no-till principles. Possibly a result of his measured pace of no-till conversion, Tom enjoyed the process of his trek, "I would tell anyone: Get started quickly, but go with some caution." Tom is a great student of no-till experts and his own operation alike. Ever cognizant of residue levels in his fields, Tom would like to see more. Enter the realm of cover crops. His rotations of grain crops were already 'maxed out,' typically with a pattern of: wheat/ dc beans (or dc corn, milo) >>corn >>beans. (On his extremely sandy soils, he omits the single-crop soybeans—he drills wheat directly into corn stalks.)

Photo by Roger Long.

On bottomland soil, Tom's thatch is brushed away to reveal a crumb structure and abundant, healthy roots from his early-planted corn. (The corn leaf is senescing from severe drought.)

Photo by Roger Long.

Pauly's June-planted corn (single-crop) begins to tassel on 4 Aug. 2011. Somehow, it bested his early April corn—again.

Although virtually every acre of Tom's wheat is double-cropped every year, his dc corn goes primarily on better river-bottom ground.

In true pioneering spirit, Pauly realizes that with cover crops, he doesn't even know all the questions, let alone the answers. "At first I was reluctant. My thinking was, 'Why not grow a cash crop?' —double-crop soybeans were doing very well!" But, after further contemplation, Pauly recognized a better window for covers: "Our corn comes off in September [then barren until May]. To me, it's a 'no brainer' to have a cover crop of oats, rye, or triticale in those corn stalks—I want lots and lots of residue. Most years, we have way more than enough moisture in the spring to let that cover grow for a long time and still plant beans easily. I've got lots of water running off the fields every spring [without a cover]." Tom would like to use that moisture to maintain and grow the soil biology and to recycle nutrients. Tom further contemplates delaying soybean planting until June to let the cover develop further: "Late beans often do better than early beans here. It's a craps shoot." But he thinks the cover-crop residue may trump planting date: "I'm looking for mulch for the soybean crop. I want to get as much as I can."

"I want lots and lots of residue."

Another window is the gap between wheat harvest and a rare stacked wheat planting: "There can be a great deal of rain between harvest and planting, although this year was an aberration," says Tom. Between wheat crops, sunn hemp is his cover of choice, which also works well if he decides to go to corn the following year instead.

When it got too sketchy for double-crop on a field in 2011, Tom tried a sunn hemp, cowpea, sunflower, sudan, milo, radish, and pearl millet mix, but with poor results—only the sudan and milo grew in the rapidly drying seedbed. Not dismayed, Pauly's trials are on limited acres so morale isn't sacrificed—Tom harkens back to one of his favorite Dwayne Beck quotes, "If you don't have a failure once in awhile, you're not pushing the rotation hard enough."

This type of admiration for self-challenge exemplifies Pauly's dichotomy of bold progressive thinking and cautious, governed implementation. In his mind, one of the best aspects of cover crops is how it confronts his thoughts and pushes him to view crop production from new vantage points. One product of this paradigm shift was to look at corn planting dates: "I used to make sure I got all my corn planted in the first two weeks of April, even if that meant hogging around in the mud. I've since learned that if it's cold and wet, I'm better off waiting—I don't fight it, I'll wait and plant at the end of May." Tom reports that his stands are much more uniform at the later planting date, and, "The last 2 years, my late-May-planted corn has outyielded my early April plantings." Tom doesn't think this is a fluke, since he got the idea from northern Oklahoma producers who'd been more successful for several years with planting corn in June, rather than the end of March. And with the success Tom's had with dc corn, he's going to try planting corn into spring cover-crop residue in early June to spread workload and pollination timing.

Firmly grounded by humility lessons doled out by Mother Nature, Pauly knows that crops in higher intensity rotations will occasionally fall short of yields pro-

Photo by Roger Long.

Tom's double-crop corn, early Aug. 2011.

duced by more conservative, standard methods. "I don't make [planning] decisions based on droughts or super wet years. I fertilize and seed for what we get on a 20-year average." He's looking for practices that will produce the greatest return in 8 out of 10 years—not 2 out of 10. For instance, he knows that wheat that follows soybeans may give up some yield in drought years, but the gains in the wet years more than offset this.

Tom's CCS drill with pull-behind liquid tank.

Photo by Andy Holzwarth.

Although some of his 2011 wheat after soybeans made only 3 – 5 bu/a, Tom did catch a couple small rains in time that he went about "business as usual" for double-cropping into the meager stubble. In Sept., he remarks on the tenacity of his dc soybeans on upland: "I just barely had enough moisture to get them up after wheat harvest. No subsoil moisture. But they held on, and by late summer I got an inch of rain two different times. That was enough that they bloomed and set pods. They're not filling very well, maybe 5 bu/a. But it's amazing what they've done on zero subsoil moisture, record-high temps for 50-some days, and just a little bit of rain."

Tom notices something else in the wake of the drought: "My residue is disappearing fast. We'll be really short on residue next spring. There's too little to grow a corn crop." In Tom's mind, this is a reason to ramp up dramatically on wheat acres this fall. (*Editors: A* cover-crop *cool-season grass would also rebuild residue cover.*) That, plus "a good insurance guarantee," says Tom, make a wheat-heavy 2012 seem like the most logical choice—which goes back to Tom's mantra, "Have a plan, but be flexible."

"I move the spray tramlines around from year to year. If I keep them in the same place, water can get to rushing down the hill."

Angle of Attack

To assist in perpetually pushing the envelope, Tom employs Andy Holzwarth as a consulting agronomist: "He thinks of things that I don't have time for." And for anyone looking at hiring an agronomist themselves, Tom advises: "Make sure they know your goals. [In my case] I want every input to give me a return on my investment." Tom notes that he's a bit less zealous than Andy in going after a few remaining weeds, yet Tom's aware of the need for diligence. Asked about glyphosate-resistant marestail, Tom says, "Andy keeps a close eye on it, so it's not out of control. We use Ignite in the spring right ahead of soybeans."

The Points North Tour introduced Tom to the stripper head, and before he harvested his next wheat crop, he purchased his own. As Tom thinks back to some of the extremely thick straw years, he's very happy with the purchase. "Residue management [with the planter] was no longer a big problem," although he makes sure to always get something planted not long after wheat harvest, so that the tall straw doesn't drift into heaps as it rots off at the soil line. Tom also recently bought a self-propelled sprayer: "I sprayed with a pull-behind sprayer always before, and never really had any qualms or problems, but after running my Miller for just awhile now—I don't know that I could go back."

"Paint won't make or break your no-till operation," quips Tom—probably because the planter he purchases is merely a blank canvas before the amendments begin. A self-described "tinkerer," Pauly is a bit of a perfectionist when it comes to seeding operations: "I enjoy putting the seed exactly where it belongs." (For Tom, this means 3 inches deep for corn on any fields that are late-planted or sandy.) On his 1770 JD, most parts touching the soil have been replaced with aftermarket products: Dawn row cleaners (that rarely get used), 3.5-mm blades, Keetons, and May Wes poly spoked closing wheels. Corn, milo, and part of his soybeans go in with the planter. Tom previously had applied pop-up with the Keetons, but now his planter-applied fertilizer is simply streamed beside the row for corn and milo. This surface side-band consists of UAN, 10-34-0, ammon. thiosul., and zinc EDTA. On sandier fields, additional N and S are side-dressed later in the season with a coulter injection rig.

For the remainder of the beans, and his wheat, Tom deploys his 7.5-inch Deere 1890 CCS no-till drill, outfitted with narrow gauge wheels, the Fin seed firmers, and Needham 20-point Crumbler closing wheels. Via the

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Fins, he applies a generous mix of 10-34-0, liquid N, and zinc for wheat.

Wheat is top-dressed twice in the spring, first at green-up (early March), and again just prior to boot-stage. The fertilizer applications, as well as a flag-leaf fungicide spray, occur in the same wheel tracks. Pauly explains, "I don't make tramlines with the drill—no blank rows. I move the spray tramlines around from year to year. If I keep them in the same place, water can get to rushing down the hill, and I don't like that at all. We need a live root mass in the track, so we need to have the crop seeded wherever the tramlines might end up being for that year. Eventually the wheels kill the crop there, but it's much better than leaving it blank."

Some no-tillers have had the added challenge of convincing landlords who staunchly believe that sound farming practices are synonymous with clean-tilled fields. To his credit, Pauly has never had a landlord refuse no-till. "Get them on board early. I've taken my landlords to a number of no-till meetings so we can hear the same information and stay on the same page." Pauly has extra high regard for the power of the rainfall simulator exhibited at numerous no-till events throughout the years: "You can tell them about the benefits [of no-till] all you want, but until they see the rainfall simulator, they don't really appreciate residue cover."

Many other aspects of no-till and good management are equally eye-opening, at least if a person pays attention as Tom does. Playing the averages, Pauly presses towards better returns.

Photo by Roger Long.

Tom's soybeans on bottomland with beautiful mulch and mellow soil. These beans made a crop in 2011 with less than 2 inches of rain, in the hottest summer on record. Thatch from the previous year's stripper-harvested wheat + double-crop corn was crucial, says Tom: "It's just amazing what we're able to do with long-term no-till and heavy residue cover."

upcoming events:

- **15, 16, 17 Nov. 2011**
  No-till on the Plains AIM Holistic Mgmt. Courses featuring Josh Dukart, Nebraska City, NE
- **24–25 Jan. 2012**
  No-till on the Plains Winter Conf. (16th Annual), Salina, KS
- **26 Jan. 2012**
  No-till on the Plains AIM Symposium, Salina, KS